Alcohol Fuel

Montana's Energy Resources

VOLUME 4

SMALL SCALE ETHANOL PRODUCTION

A few years ago, alcohol fuels received a great deal of interest because of petroleum supply problems and the potential for alcohol fuels to serve as a substitute motor fuel. Since that time, much has changed on the alcohol fuels scene. Declining oil prices and increased supplies have significantly affected the market for alcohol as a motor fuel substitute. However, markets are strong for ethanol used as a petroleum extender and octane enhancer. Ethanol produced in Montana is serving both these markets. In 1982, approximately 1,000,000 gallons of ethanol produced in Montana were blended to form gasohol, a mixture of 10% anhydrous ethanol by volume and 90% gasoline.

The ethanol industry in Montana is relatively small and can absorb more producers. Today, all of the anhydrous ethanol produced in the state is being sold, and there are unfilled orders for more. The existence of a market for the sale of ethanol does not ensure that all small-scale plants will be profitable operations. Careful consideration of all the factors involved in producing and marketing ethanol should be analyzed before making an investment decision.

This guide will serve as an introduction to ethanol production and as a reference source for additional information.

ETHANOL PRODUCTION PROCESS

Ethanol is produced by the fermentation of simple sugars. Fermentation is a biological process in which an organic substance is changed through the action of enzymes produced by microorganisms. The microorganism involved in ethanol fermentation is yeast. Enzymes convert carbohydrates from organic substances into energy for the yeast metabolic processes.

The stages involved in ethanol production are feedstock storage and preparation, fermentation, distillation, dehydration, ethanol storage, and by-product treatment.

ON THE COVER—A. E. Montana Ethanol Plant Amsterdam, Montana

BACK OF COVER—Alcotech Ethanol Plant, Ringling, Montana

Feedstocks can be selected from a variety of sugar and starch crops commonly grown in Montana. Starch feedstocks are prepared for fermentation first by mechanical grinding—in the case of grains—or crushing—such as with potatoes. Crops containing sugar, such as sugar beets, Jerusalem artichokes or fruits, are crushed and pressed in preparation for fermentation. Feedstocks are then mixed with water and heated to form a slurry or mash. In the case of starch feedstocks, fermentation preparation requires two steps, liquefaction and saccharification. During the liquefaction step an enzyme, alpha-amylase, is added to the mash and heated to 190° to 206°F. The mash is continuously stirred to break down the starch into a form of sugar called dextrin. The mash is then cooled to 140° for the second step, saccharification, which requires another enzyme, gluocoamylase, to break down the dextrin into glucose. This form of sugar can then be fermented by yeasts. Heating time, temperature and pH level must be carefully controlled during feedstock preparation. This stage takes three to twelve hours depending on enzymes and feedstocks used.

The next stage, fermentation, occurs when the mash is cooled to between 80° and 90°F and yeast is added. The yeast cells quickly multiply, consuming the glucose and giving off ethanol as a waste product. Carbon dioxide is also produced during the glucose-to-ethanol conversion. Complete fermentation can take from 36 to 40 hours when optimum temperature and pH levels are maintained. When fermentation is completed the ethanol-water mixture or beer will contain 10 to 12% alcohol by volume.

The next stage, distillation, separates the ethanol component from the beer mixture. Distillation is the separation of two compounds with different boiling points, water at 212°F and ethanol at 173°F. When the beer is heated the ethanol component and some water will vaporize first. These vapors are collected and condensed and heated again. After each successive vaporization and condensation step, a higher proof ethanol mixture is obtained. On-farm plants normally require two distillation columns. The first, a stripper column, removes about 50% of the water from the beer. The second, a rectifying column, removes up to 45% of the original volume of water. Simple distillation techniques will produce a low-grade ethanol product that is 170-190 proof.

Dehydrating or upgrading the ethanol to anhydrous ethanol (200 proof), necessary for producing gasohol, requires more complex distillation techniques or the use of molecular sieves. Molecular sieves are materials that selectively absorb water from low-grade ethanol. When low-grade ethanol is passed through a column packed with molecular sieves, the remaining water, 5 to 7%, is absorbed by the sieve material. Once the sieves become saturated with water, they can be regenerated by heating with a hot gas stream and then reused. Benzene is used in industry to dehydrate ethanol, but is very hazardous for on-farm use. Small scale plants will normally employ molecular sieves to dehydrate low-grade ethanol.

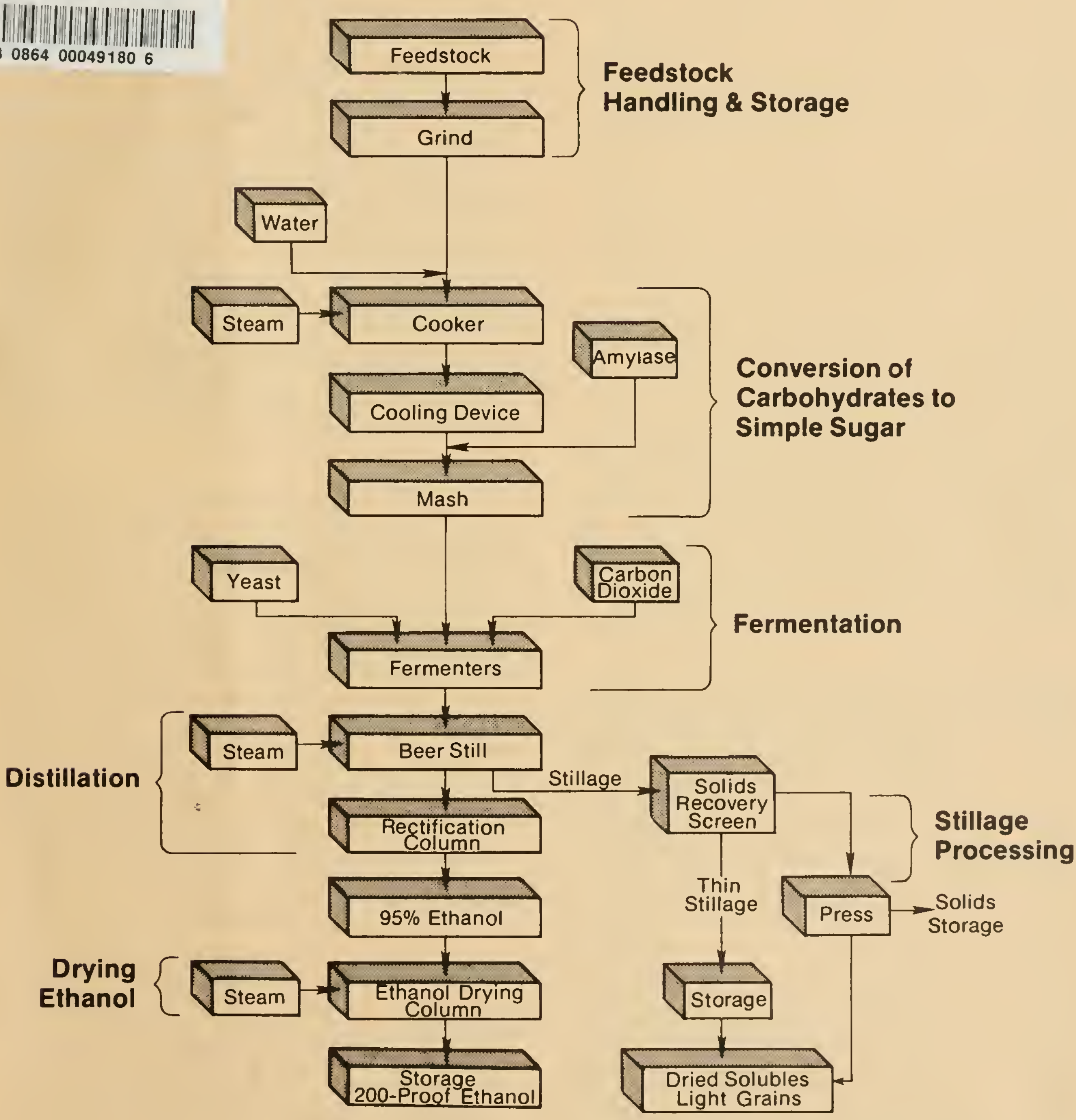

Figure 1. Anhydrous Ethanol Production Flow Chart

FEEDSTOCKS AND BY-PRODUCTS

Ethanol feedstocks can be obtained from a variety of agricultural crops. The specific feedstock selected for ethanol production will depend on the cost of the feedstock, ease of obtaining the sugar, ethanol yield and the price and quality of the by-products.

Sugar crops, such as Jerusalem artichokes and sugar beets, have the advantage of high ethanol and by-product yields per acre. Fermentation preparation costs for sugar crops are also lower than those for starch crops becuase no starch bonds need to be broken down. The high moisture and sugar content of these feedstocks cause them to spoil quickly. Long-term storage requires expensive equipment to evaporate the moisture and concentrate the sugar. Starch crops, such as corn, wheat, and barley, have the advantages of low-cost storage and high protein and economic value in the by-product. The main disadvantages of starch feedstocks are the higher labor, equipment, and energy costs associated with preparing the feedstock for fermentation.

Other feedstock possibilities include culled fruit and farm crops, food processing wastes and crop residue. These feedstocks are either short in supply in Montana or are expensive and difficult to prepare for fermentation. In Montana, wheat and barley will continue to be the primary feedstock for ethanol production until new technology and research overcomes the disadvantages of using other feedstocks.

TYPICAL AVERAGE ETHANOL YIELD VALUES

Feedstock	Gal. Per Acre	Gal. Per Ton/ Bushel
Sugar Beets	412	22.1 (ton)
Potatoes	299	22.9 (ton)
Corn	214	2.35
Wheat	79	2.57
Barley	71	1.90

Source: **Harvest and Ethanol Yields from Selected Feedstocks,** Solar Energy Research Institute, April, 1981.

Two major by-products result from the ethanol production process, carbon dioxide (CO_2) and a liquid-solid mixture known as stillage. Each gallon of ethanol produced yields 12 to 13 gallons of stillage and 6½ pounds of CO_2. Cost effective ethanol production requires that the by-products be sold or consumed on the farm. A market exists for the sale of carbon dioxide for use in the beverage industry. However, the equipment needed to recover and concentrate the CO_2 is expensive and is not economical for use in small scale ethanol plants. The stillage by-product on the other hand is relatively easy to concentrate and store and can be sold to several different markets.

Stillage is an economical and high-protein feed source or supplement. The product can be fed wet, which lowers handling and energy costs. Wet stillage spoils quickly and is only practical if a feedlot operation is located close to the plant. The stillage can also be dewatered to 60% moisture in a screwpress and mixed with straw, hay, or grain for livestock feed. A common practice is to separate the solid portion of the mixture in a dewatering screen or centrifuge and dry the product, called distillers dried grains, for storage and sale.

Research is currently underway at Montana State University on the nutritional and feeding value of barley stillage. Both wet and dry stillage from a Montana ethanol plant are being used in feeding trials on livestock. The ethanol production process concentrates the protein in stillage, usually not less than 27%, and can provide a less expensive protein source for livestock producers. During the course of six feeding trials using stillage as a beef cattle supplement, there was no growth difference noted between cattle that were fed stillage and those that were fed other protein supplements. Similar results were achieved with dairy trials. Tests conducted with sheep and pigs also showed no negative results from feed rations containing stillage.

Montana ethanol plants are also finding a market for distillers dried grains as a specialty product item. A firm in East Helena uses distillers dried grain from barley as a protein source in a packaged pet food product. The distillers dried grain is mixed with cane molasses and processed through a pelletizer. The final product is 28% protein and contains 60% digestible nutrients.

PLANT DESIGN

Figure 2. Straw Combustion Chamber

Individual plant designs are usually site specific. Engineering expertise is helpful when sizing and matching equipment to maximize production yields, plant efficiency and profitability. There are examples of owner-designed and built on-farm plants across the country that operate at high efficiency. Plants can be designed and built on-site, a common practice with smaller plants, or contracted to an equipment supplier to include design, construction and initial shakedown of the plant.

Plant design is a function of numerous interrelated factors. These include:

- amount of time an owner can commit to operating a plant;
- initial investment and operating costs that can be incurred by the owner;
- purity of ethanol produced (anhydrous ethanol plants are more complex and energy intensive);
- desired form of by-products; and
- regulations imposed on the plant by federal, state and local authorities.

Careful attention to engineering design can allow a farmer to operate a plant that will fit in with daily farm activities. Efficient and economical plants can be designed to require 2 to 3 visits per day. Larger plants (500,000 gallons of production per year) are able to operate on a much lower per unit production cost than smaller plants. The continuous operation of larger plants maximizes the value of labor, equipment, and energy inputs. However, small plants can offset this advantage by lowering some of the fixed and variable costs associated with ethanol production, such as selection of an economical heat source.

Ethanol production, whether on a large or small scale, is very energy intensive. Efficient plants can require 20,000 to 30,000 Btu's per gallon of ethanol produced, while smaller, inefficient plants may consume 40,000 to 60,000 Btu's per gallon of production. Plants that can use a low-cost renewable fuel, such as agricultural residue, can reduce plant operating costs significantly. The Bronec Fuel Company plant in Geraldine, for example, uses a straw-fired boiler for generating process heat. The straw is collected on the Bronec family farm, thus cutting fuel costs to one-sixth what they would be if the Bronecs used propane. Some plants in Montana are using coal, while others are investigating the use of waste wood boilers as a heat source.

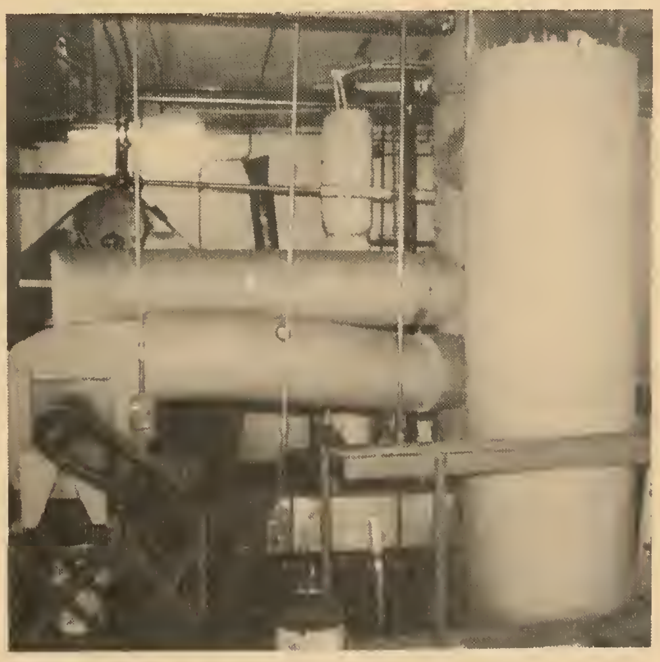

Figure 3. Steam Boiler and Dehydrator

PERMITS, REGULATIONS AND INCENTIVES

Individuals planning to operate an alcohol fuel plant must apply for a permit from the U.S. Bureau of Alcohol, Tobacco and Firearms (BATF). Bonding and other requirements are related to plant size; plants producing fewer than 10,000 gallons per year do not require a bond. Applications for permits are available from: Regional Regulatory Administrator, Bureau of Alcohol, Tobacco and Firearms, 525 Market Street, 34th Floor, San Francisco, CA 94105.

At the state level, the Department of Health and Environmental Sciences requires air and water discharge permits. A license is required from the Department of Revenue if any ethanol is sold as fuel off the farm. By-products sold as feed require registration with the Montana Department of Agriculture. The Business Licensing Center, Department of Commerce, 1424 9th Ave., Helena, MT 59620, 444-3923, will act as a clearinghouse for state licenses required when producing and marketing ethanol and by-products.

Incentives for ethanol production and consumption exist at the federal and state level. In addition to the 10% federal Investment Tax Credit for new equipment, commercial plants also qualify for another 10% tax credit for new equipment and facilities used in the production of alternate fuels. Real and personal property used in the production of gasohol in Montana is eligible for property tax reductions during the first three years of operation. Under state law, there is a tax incentive payable to alcohol distributors for distilling alcohol which is blended with gasoline for sale as gasohol. The tax incentive on each gallon of alcohol distilled is currently 70 cents. The federal government also has established an excise tax credit of 5 cents per gallon of blended fuel.

Ethanol plants in Montana are eligible to apply for loans through the Renewable Energy and Conservation Program. Loans can be used to fund the development, design, construction and marketing of an ethanol plant. For more information contact the Energy Division, Department of Natural Resources and Conservation, 32 South Ewing, Helena, MT 59620.

ON-FARM ETHANOL PLANT

BRONEC FUEL COMPANY

Bronec Fuel Company is a part of the Bronec family farm operation near Geraldine. The Bronecs have operated a farm-scale anhydrous alcohol plant since June 1982. A key feature of the plant is the process heat source, a straw-fired boiler. The plant was designed by Larry Bronec, a mechanical engineer, and built onsite. Yearly production volume is 40,000 gallons of anhydrous alcohol.

Plant Description

The plant has four double-walled 2,500-gallon cooker/fermenter tanks arranged for a batch process where cooking and fermentation steps are completed in the same tank. There are two 16-foot distillation columns and a molecular sieve dehydrator. Process heat is supplied by a 50-hp straw-fired boiler. The plant uses several heat exchangers to minimize energy inputs.

The batch process is started by filling the cooker/fermenter tanks with water preheated in a heat exchanger from a previous batch. Approximately 80 bushels of cracked barley are added and heated to 180°F by injection of steam. Enzymes are added and the mash is cooked for two hours. Cooling water is then circulated around the double-walled tanks to lower the temperature of the mash to 90°F. A precultured yeast solution is added and allowed to ferment for 36 hours. After fermentation is complete the beer is 10 to 12% ethanol. The solids in the beer mixture are separated out in a screwpress and the beer is pumped to the distillation columns. The beer is distilled to 190 proof. The ethanol is upgraded to 200 proof by passing it through the molecular sieve dehydrator. After approximately 145 gallons of the ethanol have been upgraded, the sieve materials become saturated with water and must be regenerated. Hot boiler flue gases circulated through the dehydrator regenerate the molecular sieve materials in 6 hours.

The alcohol yield is approximately 2 gallons of anhydrous alcohol per bushel of barley. In addition, each batch yields 180 pounds of distillers grain at 60% moisture. A portion of the distillers grain is fed to cattle on the farm and the remainder is sold to a nearby rancher. Most of the ethanol produced is sold to a fuel distributor in Fort Benton.

The Bronecs are pleased with the operation of their ethanol plant as a whole. By selling the ethanol and distilled grain they are getting a higher return for their barley than they did before building the plant.

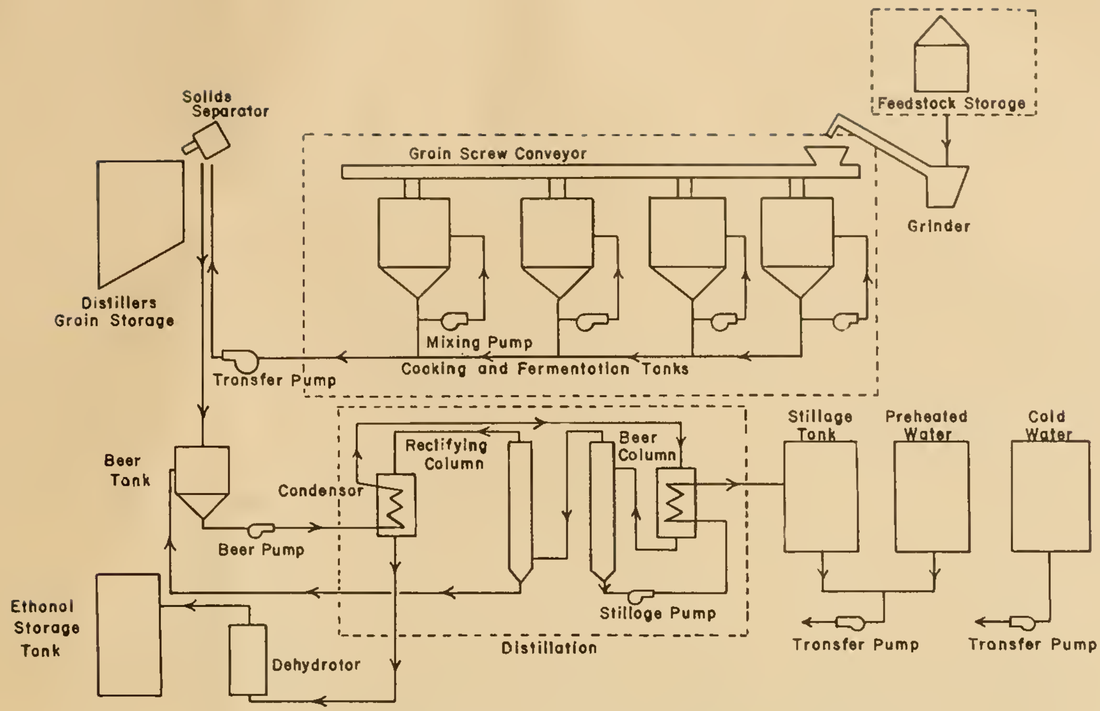

Figure 4. Ethanol Plant Process Schematic

FOR MORE INFORMATION

Government Publications

Fuel From Farms: A Guide to Small-Scale Ethanol Production provides a comprehensive guide for on-farm ethanol production. Describes fermentation procedures and offers worksheets and guidelines to help in analyzing the feasibility of operating an ethanol plant. Appendices provide feedstock data, equipment and manufacturer information, BATF regulations and a bibliography. Available free by request from the Montana Department of Natural Resources and Conservation, 32 South Ewing, Helena, MT 59620.

Small Scale Fuel Alcohol Production is a good source of information concerning small-scale, on-farm production. Emphasis is on use of alcohol fuel in vehicles and use of the stillage by-product. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington D.C. 20402.

Fermentation Guide for Common Grains describes optimum procedures for manufacturing ethanol from corn, wheat, and barley feedstocks. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington D.C. 20402.

Ethanol Fuels Reference Guide is a compendium of information compiled and disseminated by National Alcohol Fuels Information Center during its operation in 1980 and 1981. The volume is very useful to anyone considering ethanol production. Information on ethanol production processes, technical reference data, and addresses of component manufacturers, enzyme and yeast producers, etc. is provided. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington D.C. 20402.

General Introductory

Making it on the Farm—Alcohol Fuel is the Road to Independence, M. Nellis, 1979, 88 pages. Available from American Agriculture News, P.O. Box 100, Iredell, TX 76649 ($2.95).

Ethanol Production and Utilization for Fuel, Cooperative Extension Service, University of Nebraska, October 1979, 83 pages. Discussion of the suitability and availability of raw materials, production processes, utilization of ethanol and by-products, safety considerations, and economics for farm-scale plants. Available from Extension Publication Service, Cooperative Extension Sevice, University of Nebraska, Lincoln, NE 68583 ($2.00).

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